

**GUIDELINES
FOR
WET MIX MACADAM**



**THE INDIAN ROADS CONGRESS
1997**



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FOR
WET MIX MACADAM**

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GUIDELINES FOR WET MIX MACADAM

1. INTRODUCTION

Conventional Water Bound Macadam (WBM) construction is generally time consuming and manual, with copious use of water. The other disadvantage in WBM is that the segregation of aggregate takes place in the mix and the work results in non-uniformity in the finished surface. Wet Mix Macadam (WMM) construction is an improvement upon the conventional WBM and is intended to be as an alternative and more durable pavement layer. It consists of clean, crushed, graded aggregates premixed with other granular materials and water and rolled to a dense mass on a prepared surface.

The draft document prepared by Flexible Pavement Committee was discussed by the Highways Specifications and Standards Committee in its meeting held on 12th May, 1994 and it was decided that another draft prepared by Mechanisation Committee on "Wet Mix Macadam" should be clubbed with this in light of comments of members since both these items pertained to wet mix macadam. Accordingly the above drafts were referred back to the newly constituted Flexible Pavement Committee consisting of the following personnel for in-depth study:

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The above Committee in its meeting held on 24th May, 1994 requested Dr.L.R. Kadiyali to finalize the draft on WMM in light of the comments made in H.S.S. Committee on 12th May, 1994. Accordingly, the draft has been finalised by Dr. L.R. Kadiyali and was approved by the Flexible Pavement Committee in its meeting held on 13th February, 1996.

The guidelines were discussed by the Highways Standards and Specifications Committee in its meeting held on 19th March, 1996. It was decided that guidelines would have two parts: Part I would deal with the specification of Wet Mix Macadam and Part II would cover the equipments for WMM. With these modifications, the draft was approved. The guidelines approved by the Executive Committee in its meeting held on 17th April, 1996 was considered by the Council in its meeting held on 24.5.96 at Darjeeling. The guidelines were approved by the Council subject to the observations of the members, which should be considered by the Executive Committee before its publication. As decided by the Executive Committee in its meeting held on 4th September, 1996, the comments of the members were duly examined by Shri A.P. Bahadur, in consultation with the Convenor of Flexible Pavement Committee. The modified draft was approved for publication by the Executive Committee in its meeting held on 21.12.96.

PART I : SPECIFICATIONS FOR WET MIX MACADAM

2. DESCRIPTION

Wet Mix Macadam is a pavement layer wherein crushed graded aggregates and granular material, like, graded course sand are mixed with water in mixing plant and rolled to a dense mass on a prepared surface. It has many advantages over the WBM construction. These include superior gradation of aggregate, faster rate of construction, higher standard of densification that can be achieved, less consumption of water and stricter standards of quality achievable. The specification can be adopted for sub-base and base courses. The work may be done in many layers. The thickness of an individual layer shall not be less than 75 mm and can be upto 200 mm provided suitable type of compacting equipment is used.

3. MATERIALS

3.1. Aggregate

3.1.1. Physical requirements: Coarse aggregates shall be crushed stone/crushed gravel/shingle, not less than 90 per cent by weight of gravel/shingle pieces retained on 4.75 mm sieve and shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table 1.

If the water absorption value of the coarse aggregates is greater than 2 per cent, soundness test shall be carried out on the material as per IS:2386 (Part V).

Table 1. Physical Requirement of Coarse Aggregates for Wet-Mix

	Test	Test Method	Requirements
1. *	Los Angeles Abrasion Value or * Aggregate Impact Value	IS:2386 (Part IV)	40 per cent (Max)
		IS:2386 (Part IV or IS:5640)	30 per cent (Max)
2. **	Combined Flakiness and Elongation indices (Total)	IS:2386 (Part I)	30 per cent (Max)***

* Aggregates may satisfy requirements of either of the two tests.

** To determine the combined proportion of flaky and elongated particles, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (Non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The value of flakiness index and elongation index so found are added up.

*** Requirement of 30 per cent can be relaxed upto 35 per cent (only) in cases where WMM is to be used as sub base.

3.1.2. **Grading requirements:** The aggregates shall conform to the grading given in Table 2.

Table 2. Grading Requirements of Aggregates for Wet Mix Macadam

IS Sieve Designation	Per cent by Weight Passing Sieve	
	Grading 1	Grading 2
53.00 mm	100	
45.00 mm	95-100	
26.50 mm		100
22.40 mm	60-80	50-100
11.20 mm	40-60	
4.75 mm	25-40	35-55
2.36 mm	15-30	
600 micron	8-22	10-30
75 micron	0-8	2-9

Material finer than 425 micron shall have Plasticity Index (PI) not exceeding 6.

The nominal size of aggregate to be used in a given case would depend on availability. While both the grading can be used for base/sub-base courses, course using Grading No.1 shall not be laid over the course using Grading No.2

The final gradation within the limits set forth in Table 2 shall be well graded from coarse to fine and shall not vary from the lower limit on one sieve to the higher limit on the adjacent sieve or vice versa.

4. CONSTRUCTION OPERATIONS

4.1. Weather and Seasonal Limitations

The work of laying of wet mix macadam shall not be done during rain.

4.2. Preparation of Base

The surface of the sub-grade/sub-base/base to receive the WMM course shall be prepared to the specified lines and cross-fall (camber) and made free of dust and other extraneous matter. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm surface is obtained, if necessary by sprinkling water.

As far as possible, laying of WMM course over an existing thick bituminous layer may be avoided since it will cause problems of internal drainage of the pavement at the interface of two courses. It is desirable to completely excavate the existing thin bituminous wearing course where WMM is proposed to be laid over it. However, where the intensity of rain is low (less than 1300 mm), and the interface drainage is efficient, WMM can be laid over the existing thin bituminous surfacing by cutting 50 mm x 50 mm furrows at an angle of 45 degrees to the center line of the pavement at one meter intervals on the existing road. The directions and depth of furrows shall be such that they provide adequate bondage and also serve to drain water to the existing granular base course beneath the existing thin bituminous surface.

4.3. Provision of Lateral Confinement of Wet Mix

While constructing WMM, arrangement shall be made for the lateral confinement of wet mix. This shall be done by laying materials adjoining shoulders alongwith that of wet mix layer. The sequence of operations shall be such that the construction of the shoulder is done in layers each matching the thickness of the adjoining pavement layer. Only after a layer of pavement and corresponding layers in shoulder have been laid and compacted, the construction of the next layer of pavement and shoulder shall be taken up.

4.4. Preparation of Mix

WMM shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/positive mixing arrangement, like, pugmill or pan type mixer. For small quantity of wet mix work, mixing may be done in ordinary concrete mixers. The Specifications and requirements for equipment for WMM are discussed in Part II. The equipment should conform to requirements detailed in Part II.

Optimum moisture for mixing shall be determined in accordance with IS:2720 (Part VIII), after replacing the aggregate fraction retained on 19 mm sieve with material of 4.75 to 19 mm size. However, the OMC and required number of passes to achieve the desired density may be determined at site during proof rolling, using the roller selected for compaction. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary by more than ± 1 per cent.

4.5. Spreading of Mix

Immediately after mixing, the mixed material shall be transported to site and spread uniformly and evenly upon the prepared subgrade/sub-base/base in required quantities. Hauling of the mix over a freshly completed stretch is not permitted.

The mix may be spread either by a paver finisher or motor grader or a combination of both. However, the use of paver finisher should be preferred to motor grader for spreading. For portions where mechanical means cannot be used, manual method of spreading can be adopted. The equipment used for spreading shall be capable of spreading the material uniformly all over the surface. Its blade shall have hydraulic controls suitable for initial adjustments and maintaining the same so as to achieve the specified slope and grade.

The paver finisher shall be self-propelled, having the following features:-

- i) Loading hoppers and suitable distributing mechanism
- ii) The screed shall have tamping and vibrating arrangement for imparting initial compaction to the layer as it is spread without rutting or otherwise disturbing the surface profile.
- iii) The paver shall be equipped with necessary control mechanism so as to ensure that the unfinished surface is free from surface blemishes.

The surface of the layer as spread shall be carefully checked with templates and all high or low spots remedied by removing or adding wet mix

material as may be required. The layer thickness may be checked by depth blocks during construction. No segregation of coarse or fine particles shall be allowed. The layer as spread shall be of uniform gradation and shall not have pockets of fine materials.

4.6. Compaction

After the mix has been laid to the required thickness, grade and cross-fall/camber, the same shall be uniformly compacted to the full depth with a suitable roller. If the thickness of the single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100 kN weight may be used. For compacting single layer of higher thickness upto 200 mm, the compaction shall be done with the help of vibratory roller of minimum 80-100 kN static weight or equivalent capacity to achieve the desired density. The speed of roller shall not exceed 5km/hr.

In portions having uni-directional cross-fall/superelevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter roller should progress parallel to the center line of the road, uniformly over-lapping each preceding track by at least one-third width until the entire surface has been rolled upto the centre line. The process of compaction is then to be repeated from the other edge of the pavement upto the centre line, until the entire pavement is compacted. Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected.

Along forms, kerbs, walls or other places not accessible to the roller, the mix shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

Rolling should not be done when the subgrade is soft or yielding or when it causes a wave-like motion in the sub-base/base course or sub-grade. If irregularities develop during rolling which exceed 12 mm when tested with a 3 meter straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross-fall. In no case should the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is atleast 98 per cent of the maximum dry density for the material as determined by the method outlined in IS:2720 (Part VIII).

After completing, the finished surface shall present a well-closed appearance, free from movement under compaction equipment or any compaction marks, ridges, cracks and loose material. All loose, segregated or otherwise

defective areas shall be made good to the full thickness of the layers and recompactd.

Longitudinal joints and edges shall be constructed true to the delineating line parallel to the centre line of the road. All longitudinal and transverse joints shall be cut vertical to the full thickness of the previously laid mix before laying the fresh mix. .

4.7. Important Considerations in Construction Process

While due care and attention is required on the whole process of WMM construction, the following are important points needing more attention:-

- i) Sometimes because of moisture in the fines, these will not flow out from the bin of the three-bin feeder to the belt. In such situation, it would be necessary to have a small vibrator fitted on one of the side walls of the bin to intermittently shake it.
- ii) Control on water in the mix is of utmost importance; hence there should not be any variation in the grading, particularly of fines as it will effect the moisture content and uniform mixing. Similarly, excessive fluctuations in the moisture content of the fines should be avoided. If necessary, slight increase may be made in the moisture contents to account for the moisture loss in transit to the laying site.
- iii) Excessive silt or clay in fines should not be permitted, as besides spoiling the quality of mix, it will cause clogging in pugmil and storage silo.
- iv) The mixed material should be transported directly to site. Stockpiling of mixed material should be discouraged as excessive handling is the cause of segregation and moisture loss, both of which are detrimental to the quality of the wet mix macadam.
- v) There should be minimum joints in laying wet mix macadam. To ensure this, the daily output should at least be 500 linear meters. The width of laying also should be so adjusted to avoid the necessity of laying narrow strips e.g. against kerbs.
- vi) Single paver of 7m width or two pavers each of 3.5m width working in tandem within the short distances should be used for obtaining good results.

4.8. Setting and Drying

After final compaction of the wet mix macadam course, the road shall be allowed to dry for 24 hours before overlaying with any bituminous layer.

5. OPENING TO TRAFFIC

No vehicular traffic except construction vehicles shall be allowed on the finished WMM surface till the subsequent bituminous course is laid.

6. SURFACE FINISH AND QUALITY CONTROL OF WORK

6.1. The surface levels of a wet mix layer laid as a sub-base shall have a tolerance of not more than + 10mm and -20mm from the designed longitudinal and cross profile. When laid as a base course with machines, the tolerance shall be +10mm and -10mm. For checking compliance with this, surface levels shall be taken on a grid of points placed 6.25 m longitudinally and 3.5 m transversely. For any 10 consecutive measurements taken longitudinally or transversely, not more than one measurement shall be permitted to exceed the above tolerances, thus one measurement being not in excess of 5mm above the permitted tolerance.

6.2. The longitudinal profile shall also be checked by a 3 meter straight edge at the middle of each traffic lane along a line parallel to the centre line of the road. The maximum allowable difference between the road surface and underside of a 3 meter straight edge shall be 8 mm.

The frequency of the Quality Control tests shall be as under:

1.	Gradation	One Test per 200 m ³
2.	Plasticity Index	One test per 200 m ³
3.	Moisture Content prior to compaction	One test per 250 m ²
4.	Density of compacted layer	One test per 500 m ²
5.	Aggregate Impact Value or Los Angeles Abrasion Value	One test per 500 m ³
6.	Flakiness and Elongation Index	One test per 500 m ³

6.3. For testing the compaction requirements, test locations shall be chosen only through random sampling techniques. Control shall not be based on the result of any one test but on the mean value of 5-10 density determinations. The number of tests in one set of measurements shall be 6 (if non-destructive tests are carried out, the number of tests shall be doubled) as long as it is felt that sufficient control over the constituent materials forming the mix is being exercised. If considerable variations i.e. 15% and above are observed between individual density results, the minimum number of tests in one set of measurement shall be increased to 10. The acceptance criteria shall be subject to the condition that the mean density of a set of measurement shall not be less than the specified density plus:

$$1.65 - \frac{1.65}{\sqrt{(\text{No. of samples})}} \times \text{standard deviation}$$

6.4. Rectification of Surface Irregularity

Where the surface irregularity of the layer as laid exceeds the permissible tolerances or where the course is otherwise defective due to subgrade soil getting mixed with the aggregates, the full thickness of the layer shall be scarified over the

affected area reshaped with added premix material or removed and replaced with fresh premix material and recompact. The area treated in this manner shall not be less than 5 m long and 2 m wide. In no case shall depressions be filled up with unmixed and ungraded material or fines.

7. MEASUREMENT FOR PAYMENT

Wet mix macadam shall be measured as finished work in position in cubic meters.

PART II : EQUIPMENT FOR WET MIX MACADAM

8. CONSTRUCTION PROCESS

The construction process of wet mix macadam involves the following sub-activities:-

- i) Production of aggregates in required sizes.
- ii) Proportioning of aggregates and mixing with water.
- iii) Transportation of mix.
- iv) Spreading and laying.
- v) Compaction.

The whole process should be such that methods adopted and equipment used meet the laid down requirements of end result specifications in respect of sizes and grading of aggregates, optimum moisture content, proper mixing, laying in uniform thickness to the correct profile and required compaction.

9. EQUIPMENT NEEDS

The equipment requirement for WMM is simple. Most of the equipment needed for other activities like stone crushers, tippers, motor grader, paver and vibratory roller can be used for this work too. Few additional equipment can be a three-bins feeder, pugmill etc. For some work more than one type of equipment can be used. The pros and cons of some of these are discussed below along with the activity-wise requirement.

10. PRODUCTION OF AGGREGATES

Multi-stage stone crushing and vibratory screening plant installed for obtaining aggregates for bituminous courses can easily meet the requirement of wet mix macadam. Wider variation in the quantities of different fractions are permissible in some cases.

11. PROPORTIONING OF AGGREGATES AND MIXING

11.1. Proportioning and mixing can be done in different ways depending on the total methodology of work adopted.

11.2. Concrete Mixer

For small quantities of WMM, concrete mixer can be used for production of mix and different fractions can be added by box measurement as in the case of manual feeding of mixer for producing concrete. In this method, the usual facility of measuring water is a overhead tank which will not be very accurate. Further, because of limitations such as the size and capacity of mixer, manual feeding and non-continuous production of mix makes, this method is unsuitable for large scale work.

11.3. Batching and Mixing Plant

11.3.1. In order to obtain uniform WMM material using batch plant, only pan type mixing plant should be used, since it provides the force mixing of the different constituents of the mix. The mixing time may have to be increased for more uniform dispersal of low water content in the mix. Blending of aggregates and mixing can be achieved through storage bins and weigh hoppers.

11.3.2. Bin feeder & pugmill

For continuous production of mix in a pugmill in sufficient quantity, the best way to feed the aggregates and control the grading is by means of a 3 or 4 bins feeder with belt conveyor. It is similar to the bin feeder of a hot mix plant but without variable speed motors and load sensor as the required grading can be achieved with the adjustment of gate openings itself. Such a unit consisting of 3 or 4 bins feeder, belt conveyors, pugmill and water pump arrangement is the most suitable equipment for production of wet mix macadam. A typical layout of 60 tons per hour capacity plant is given at *Annexure 1*.

11.3.3. **Important features :** The following are some of the important features to be kept in view :

- i) Under each bin, there should be an adjustable quadrant gate and belt feeder to regulate the aggregate supply.
- ii) Giggli screen should be provided over the coarse aggregate bins to exclude oversize material, if any.
- iii) A surface vibration should be provided on the outside of the sand/fines bin to maintain uniform flow.
- iv) Belt feeder, gathering conveyors and secondary conveyor should have independent motors.

- v) The angle of inclination of secondary conveyor should not be more than 19 degrees.
- vi) The twin-shaft pugmill should have replaceable inner liner plates.
- vii) The clearance between the tips of the paddles and liners should be less than maximum stone size so that the aggregates are pushed forward while mixing. This type of paddles should be adjustable so that clearance can be set according to maximum size of aggregate.

The mixing of aggregates and water is done in a continuous twin-shaft pugmill or paddle mixer. Unlike a drum mixer where mixing is achieved by rotation of the drum and flights inside it, there is forced action-mixing in a pugmill which is better for uniform coating of film of moisture. As such the use of Drum Mix Plant is not suitable for producing WMM. The controlled amount of water is added in the pugmill by a spray bar with the help of a variable speed pump and a flow meter. This arrangement provides a precise control on the quantity of water which is very critical for the success of WMM construction. In this method, feeding of aggregates, addition of water and mixing are continuous operations. The mix can be either directly discharged into the tipping truck or taken through a belt conveyor to a storage silo. It is advantageous to have a storage silo, as it helps in continuous production of mix even when no tipping truck is readily available for loading. Also loading of tipper through storage silo takes less time. Thus there will be saving in the number of tipping trucks required.

12. TRANSPORTATION

Transportation of mix is usually done by tipping trucks.

In order to avoid moisture loss in transit due to evaporation, mix should be covered with Tarpaulin.

13. SPREADING AND LAYING

For this job, there are two clear alternatives in the choice of equipment. These are motor grader and paver finisher. Both these are suitable for the work.

Advantages and disadvantages of paver finisher and motor grader are detailed below:-

1) Paver Finisher

Advantage	Disadvantage
a) Produces uniform and level surface.	a) Difficult to adjust screed every time to vary the thickness of layer in order to maintain to top level.

- b) Better control of thickness and profile of the layer.
- c) Paver has the facility of precompacting the layer and hence the surface finish is better.
- d) Initial cost of the mechanical paver is low.
- e) No wastage of wet mix macadam while laying as there is no side flow of the mix.
- b) Wear & tear of auger and chain are frequent; as such maintenance cost is high.
- c) Maximum gap between auger and side plate should not be more than 15cm, otherwise the spaces will have to be fill manually, which in turn will not be properly compacted leading to difficulty in maintaining the levels.

ii) Grader

Advantage

- a) Faster to work.
- b) Can work on slightly imperfect sub-grade.
- c) Require less maintenance.
- d) Heavy tyres helping consolidating material in depressions and the layers.

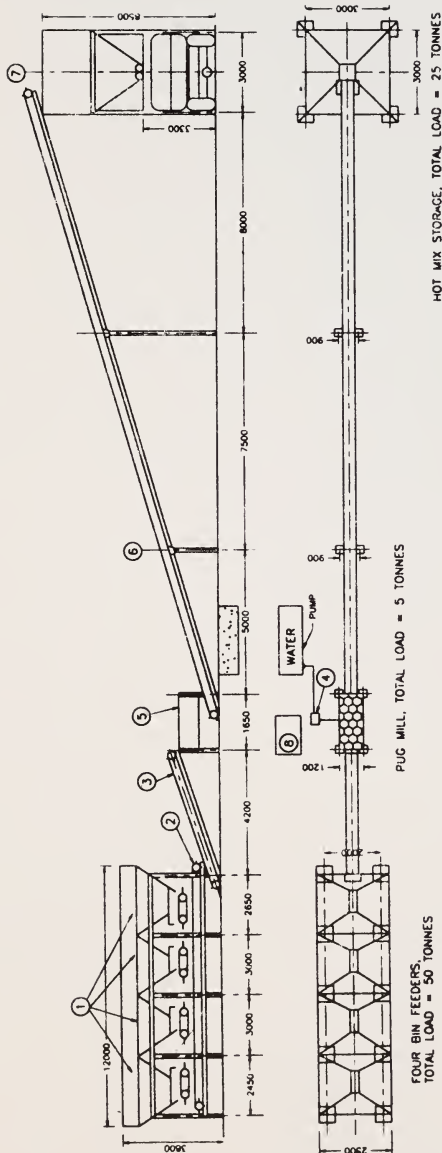
Disadvantage

- a) Less accurate in profile and surface finish.
- b) Waste of material is high due to side slippage of the mix.
- c) Lack of uniformity and proper levelling of layers.
- d) Initial cost of motor-grader is very high.
- e) Mix is dumped in heaps before spreading by the grader which is against the specification of the methodology.
- f) An efficient grader operator is required to spread the material properly. There is segregation of the particles when the mix is dumped in heaps.

Annexure-1

ANNEXURE 1

LAYOUT OF WET MIX MACADAM PLANT (CAPACITY = 60 TPH)



NOTE : ALL DIMENSIONS IN MM
(NOT TO SCALE)

1. 4 AGG. BINS WITH BELT FEEDER
2. GATHERING CONVEYOR
3. SECONDARY CONVEYOR
4. WATER METER WITH PIPE LINE
5. 60 TPH CONTINUOUS TYPE PADDLE MIXER
6. LOAD OUT CONVEYOR
7. 25 T. STORAGE SILO
8. CONTROL PANEL

